Design and Synthesis of Novel Fire Retardant Polymers for Space Exploration

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Introduction

- New technologies for space exploration bears newfound fire safety challenges to tackle.
- Current fire-retardant (FR) polymers are not versatile in application and are toxic upon combustion.
- A novel polymer containing sulfide and pyridinium salt moieties will be synthesized and investigated.

Objectives

- To synthesize a new fire-retardant polymer possessing:

Improved FR capabilities
Electronics/clothing fireproofing
Toxic combustion byproducts
Diverse applicability

- To characterize the final polymer by [1]H nuclear magnetic resonance (NMR) spectroscopy and elemental analysis (EA).
- To determine the fluorescence properties through UV-Visible spectroscopy and fluorometry.
- To determine fire-retardant capabilities by microcalorimetry.

References

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2. M. M. Alam, U. Sampathkumaran, K. Goswami, and P. K. Bhowmik. Durable and Nonflammable Crew Clothing Utilizing Phosphorous-based Fire-Retardant Materials. ICES-2014-043, 2327-2341, 44th International Conference on Environmental Systems, 13-17 July 2014, Tucson, Arizona.
3. P. K. Bhowmik and H. Han. Fire Retardant Polymers. PCT Int. Appl. Pub. 2024, WO 2024059532 A2.
4. P. K. Bhowmik, K. Goswami M. M. Alam and H. Han. Fire Retardant Materials and Devices Including Same. US Patent 10,240,090 B2, 2019.
5. P. K. Bhowmik, K. Goswami M. M. Alam and H. Han. Fire Retardant Materials and Devices Including Same. EP Patent 3,186,308 B1, 2018.
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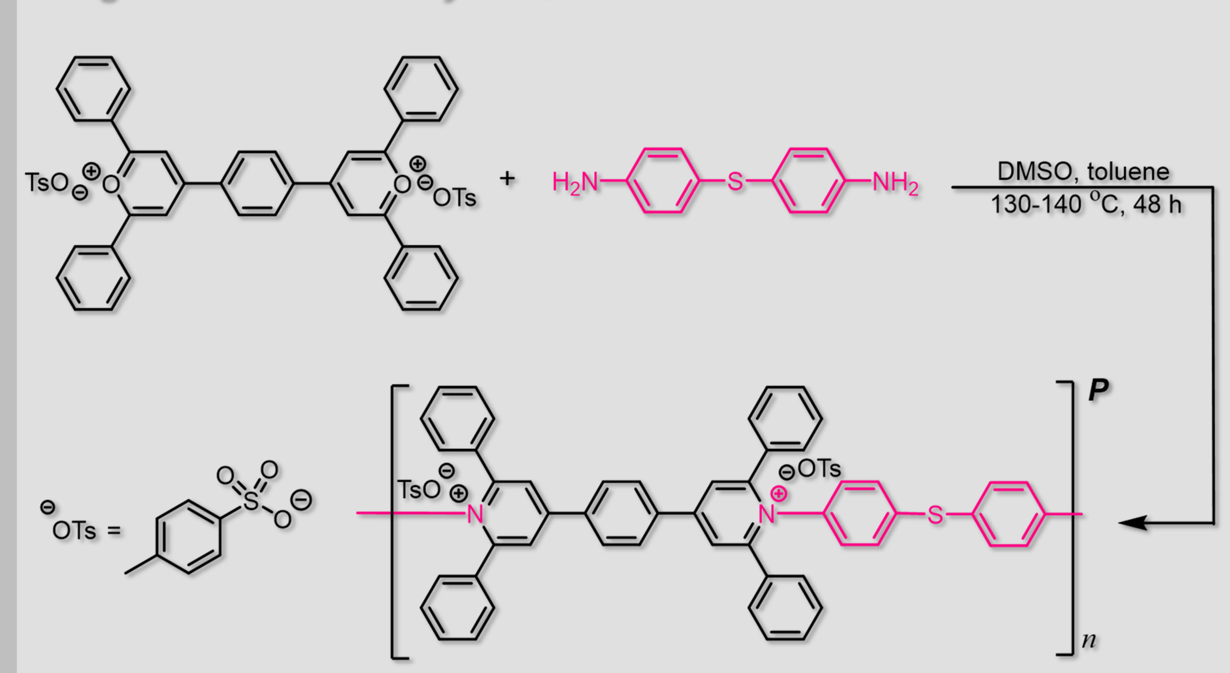
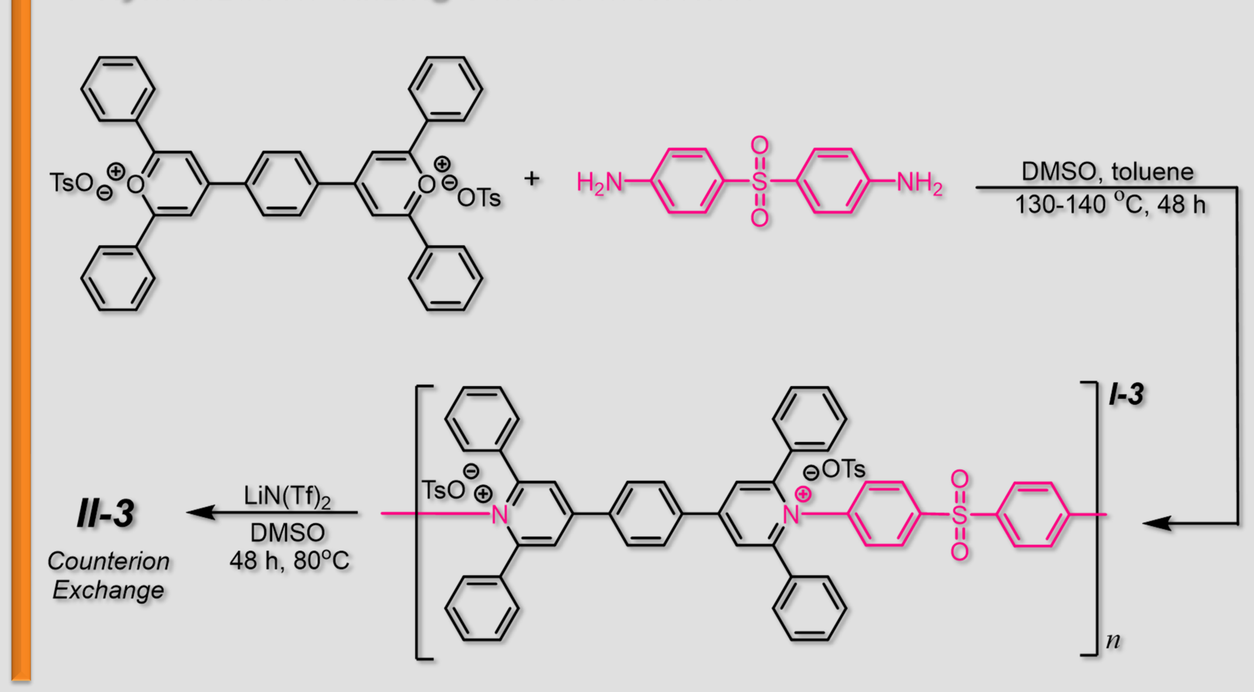
Synthetic Methods



Scheme 1. Synthesis of sulfide containing polymer *P*.



Scheme 2. Synthesis of alternative sulfone polymers *I-3* and *II-3*.

Results

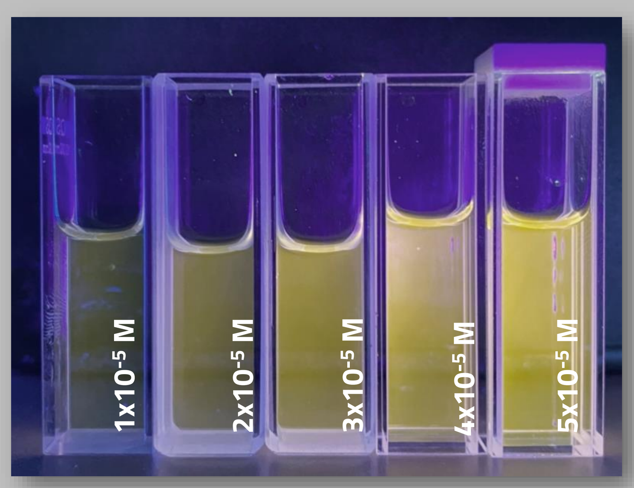


Figure 1. Dilute concentrations of *P* in methanol (10^{-5} M) exhibiting fluorescence under UV-light.

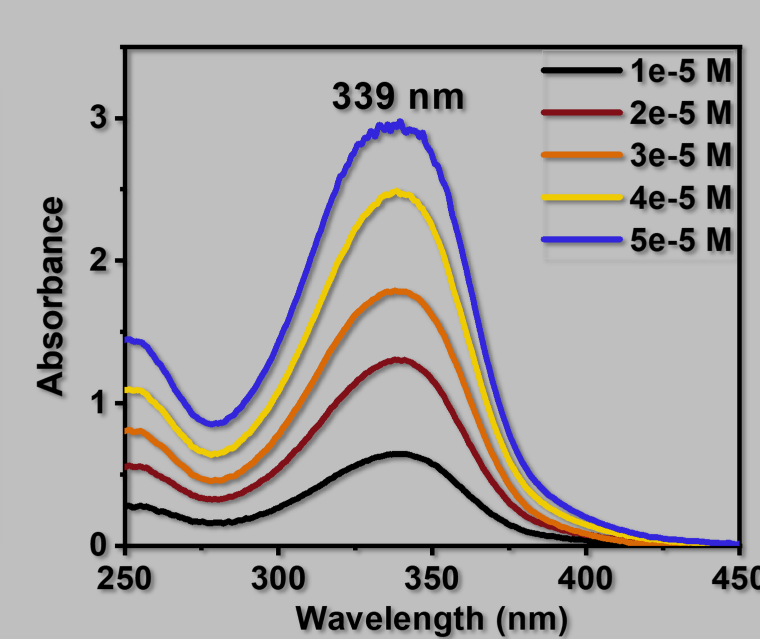


Figure 3. UV-Visible absorption spectra of *P* in methanol.

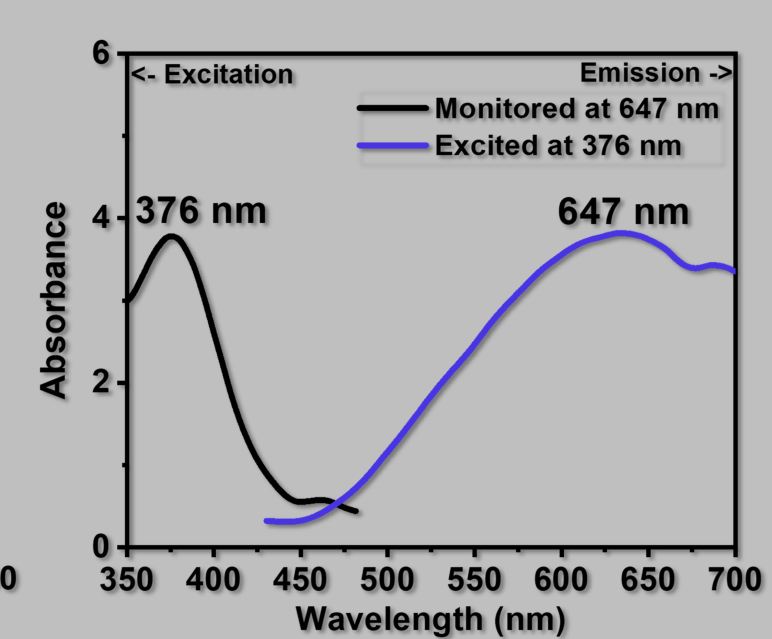


Figure 4. Emission/Excitation spectra of *P* in methanol.

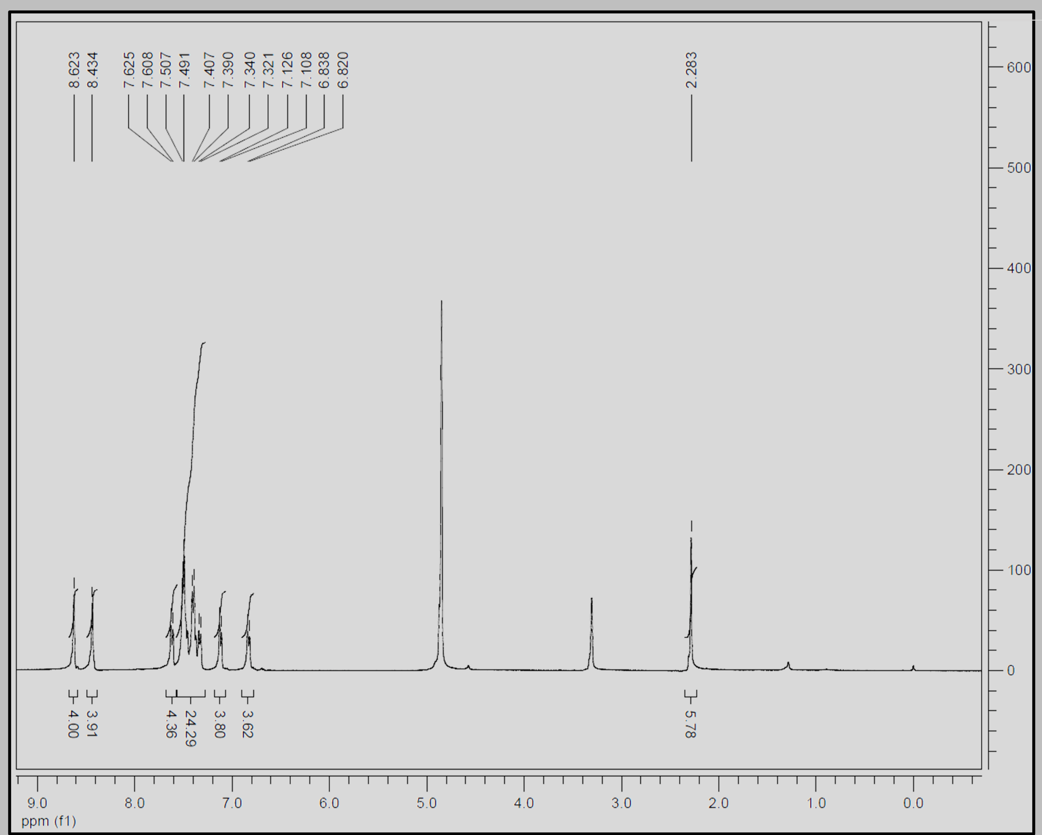


Figure 2. [1]H NMR spectrum of *P* in DMSO-d_6.

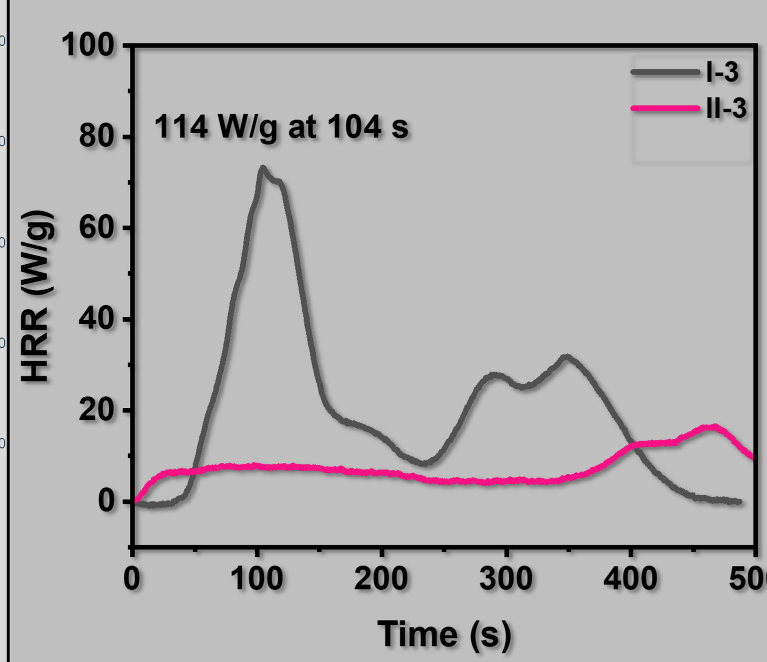


Figure 5. Microcalorimetry data of *I-3* and *II-3* plotted against time.

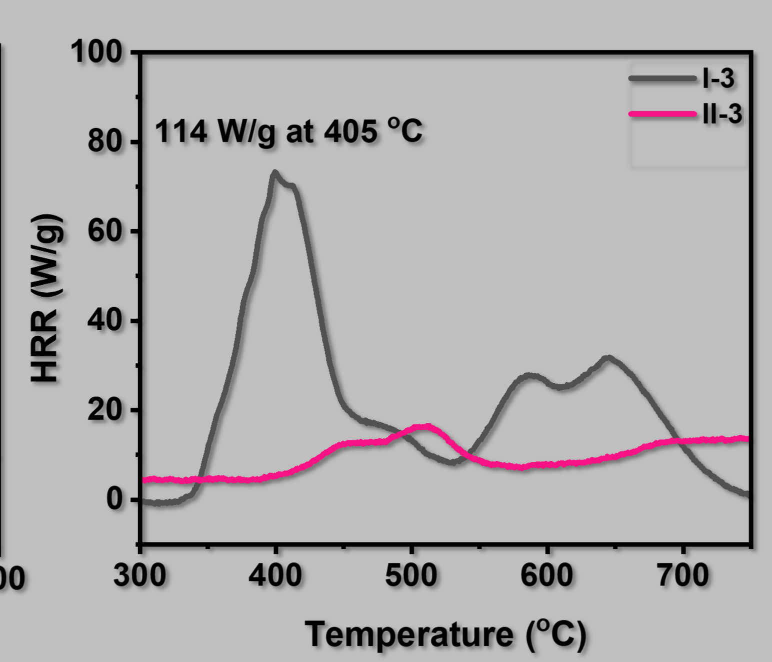


Figure 6. Microcalorimetry data of *I-3* and *II-3* plotted against temperature.

Conclusions

- A sulfide polymer was synthesized but was not fire-retardant.
- Two alternative sulfone polymers were synthesized and assessed for their fire-retardant capabilities.
- The microcalorimetry data for *I-3* and *II-3* exhibited remarkable fire-retardance.
- The UV-Vis spectrum shows a λ_{max} peak at 336 nm in methanol.
- The polymers are soluble in common organic solvents, aiding in its versatility in application.

Future Work

- The final polymers can undergo ion exchange reactions to enhance fire-resistant properties for textiles, electronics and electric vehicles.
- Structural modifications for *ortho* and *para* positions possess different molecular properties (solubility, fire-retardance, etc.)
- Expanded materials testing such as wires, car batteries, and other fire-prone materials.
- Measurement of fluorescence properties will be done in different solvents.
- Assessment of different synthetic routes for the goal of large-scale synthesis/commercialization for consumer and industrial use.

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Nevada NASA Space Grant Consortium
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